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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Development of Aircraft Engine Design and Lubrication

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LUBRICATION

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Development of Aircraft Engine Design and Lubrication

THERE has been romance attached to virtually every development in engineering. The generation and application of steam, the attainment of mass production in the automotive industry and the extended use of compressed air are typical examples of what the perseverance of the research scientist coupled with the designing and constructive ability of the engineer have accomplished.

To many, however, the marked advance in aeronautics, and especially the perfection of the aircraft engine, stands forth as the most vivid contribution of science to the history of engineering. Certainly, they have been the most spectacular.

It is needless to state that the aircraft engine is today a practical, dependable piece of equipment. The ability of certain types to function continuously for periods of fifty hours or more without a stop under most intensive operating conditions is indicative of this. In terms of miles at an average flying speed of one hundred miles per hour, this would amount to a distance of approximately one-fifth of the distance around the world. In other cases high speed racing planes have developed above 300 miles per hour.

These are astounding instances of flying time, distance and speed. And yet it is predicted that they will become but a matter of secondary consideration within the next decade.

There is, however, one proviso attached to such remarkable engine performance, viz.: Effective lubrication. For the aircraft engine, to function efficiently with a maximum development of power and speed, must be assured of protection of its wearing elements, and those of all accessory equipment, as for example, the supercharger and magneto.

Distinct problems of lubrication pertinent to no other type of mechanism are involved virtually throughout the aircraft power plant. Extremely low clearances within certain types of sleeve or plain bearings and the extraordinarily high speeds at which superchargers operate are instances of the service which aircraft engine oils must meet.

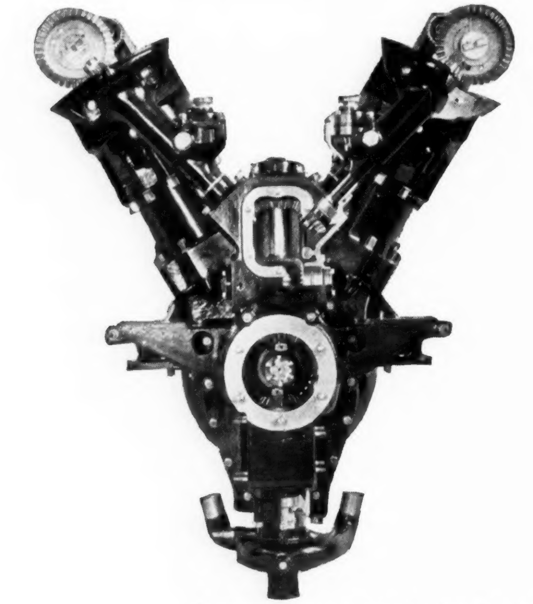
ENGINE OIL REQUIREMENTS

The essential characteristics which such oils should therefore possess are:

1. An ability to withstand abnormal change in viscosity or fluidity under prevailing operating or starting conditions.
2. Low carbon residue content, and
3. A minimum tendency to develop gummy residues which might clog the lubricating system and retard free circulation of oil.

It has been proven that straight mineral oils, or in certain types of engines a mineral-fatty oil compound, will best meet these requirements. The former are chiefly used in the United States. They may be either straight distilled products, or blends made from distillates plus highly refined residuals, such as steam cylinder stocks. The purpose of blending is to gain added viscosity to meet conditions of operation which may involve abnormally high pressures or temperatures.

The science of petroleum refining has been extensively adapted to the manufacture of such products. A most interesting feature has been the ability to obtain *distilled* oils from crudes of selected base which will have a viscosity as high



Courtesy of Curtis Aeroplane & Motor Co., Inc.
Fig. 1—Cut-away view of the Curtis "V" type (D-12) engine showing in particular the gears involved, and method of power transmission from the crankshaft.

as 90 to 100 seconds Saybolt at 210 degrees F. Among the advantages of such products is their normally low carbon residue. This will be a decided factor in the reduction of the possibility of development of residues in the lubricating system or around the piston rings.

On the other hand, research in connection with certain Vee-type engines has indicated that a blended oil, viz.: A straight mineral product containing a slight percentage of selected fatty oil may be advantageous by reason of the increased degree of oiliness which is imparted by the fixed oil content. It is, however, reasonable to presume that there might be increased possibility of development of gummy residues, for virtually any fatty oil will have this tendency when worked under fairly high temperatures for any length of time.

In fact this is one reason why castor oil has been so extensively supplanted by petroleum lubricants in aircraft engines of especially the radial, vertical and Vee types. It is still preferable, however, to use castor oil in rotary type engines, where principles of design will call for contact of the lubricant with the fuel. In such cases mineral oils, of course, would be so cut back or reduced in viscosity by gasoline as to seriously reduce their subsequent lubricating ability.

Another reason why castor oil has lost favor in connection with fixed type engines has been lack of dependable supply of the properly refined product in the United States. In France, however, conditions of supply are such as to still render castor oil a preferred lubricant according to certain authorities.

U. S. Government Aircraft Oil Specifications

In connection with this matter of aircraft engine oil requirements it will be interesting to note the following specifications as adopted by the U. S. Government, viz.:

Name and Grade	Flash Cleveland Open Cup	Viscosity Saybolt Sec. 210° F.		Pour	Carbon Residue
	Min. °F.	Min.	Max.	Max. °F.	Max.%
Liberty Aero, Grade 1	400	75	85	15	1.5
Liberty Aero, Grade 2	400	90	100	30	2.0
Liberty Aero, Grade 3	450	90	100	45	2.5
Liberty Aero, Grade 4	450	115	125	45	2.5

Reason for Viscosity Requirements

It will be observed that viscosities required are higher than in average automotive service. The reason for this is the frequently higher engine temperatures which will prevail, the necessity for service under higher pumping pressures, and the desirability of keeping oil consumption as low as possible in order that the amount of oil carried may be reduced.

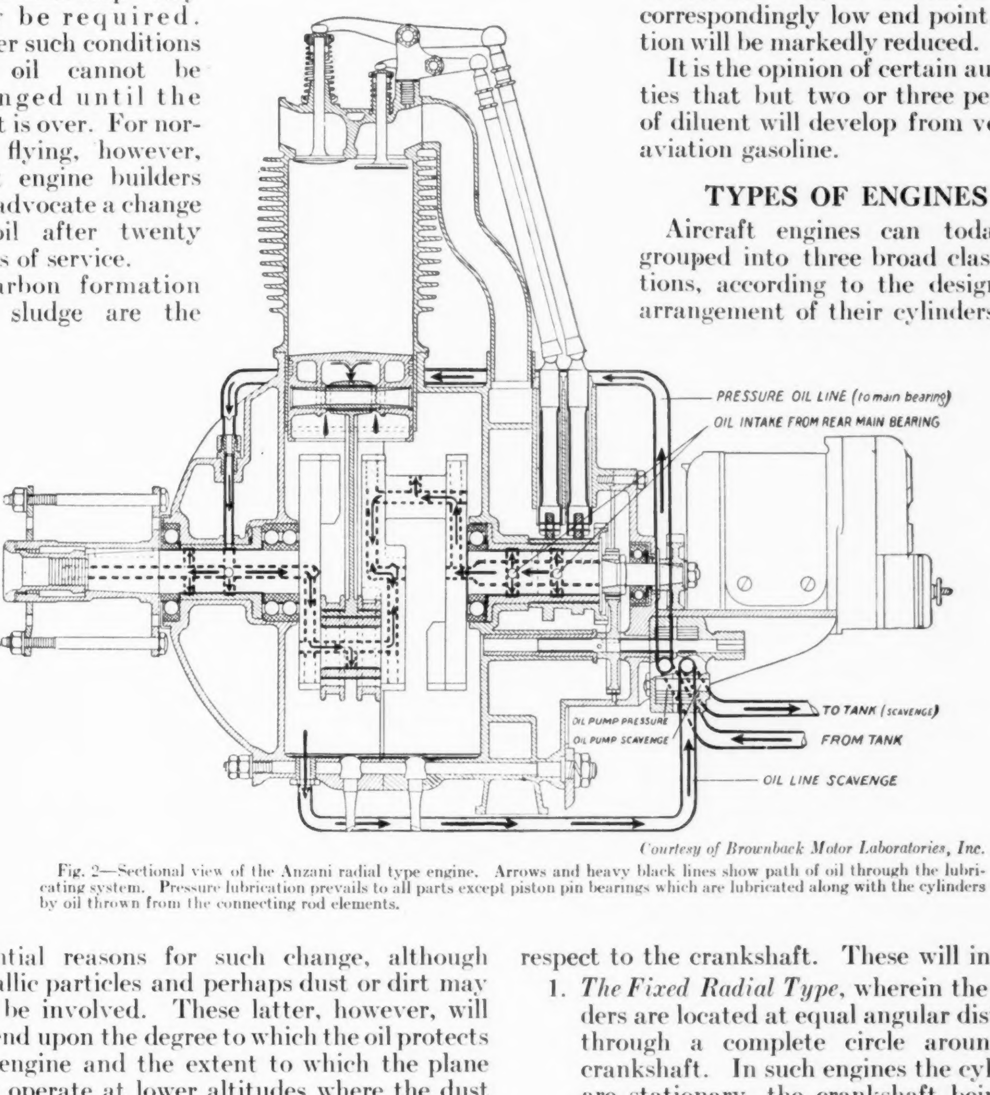
The higher the temperature, of course, the greater will be the degree of fluidity of any lubricating oil. Such conditions will be especially apt to develop in warm weather flying when the amount of external cooling will be appreciably lower than in cold weather or at high altitudes.

It is therefore essential to observe the utmost care in the selection of the proper grade of airplane engine oil which will have a viscosity in conformation with the probable flying and operating temperatures. Haphazard choice in warm weather, for example, may be the forerunner of an excessive reduction in the fluidity of the oil in service, with oftentimes ineffectual lubrication of certain of the wearing parts of the engine, as well as abnormal increase in the rate of consumption. The ultimate occurrence of scored or burned out bearings, of abnormal wear on cylinder walls and an excess of oil pumping past the piston rings, will all lead to decrease in power output and probably increased cost in engine maintenance.

Dilution and Oil Changing

Flying service in the average radial or Vee-type aircraft engine will range from five to ten hours, except in long distance flights. In the case of the latter from twenty to perhaps fifty hours non-stop duty may be required. Under such conditions the oil cannot be changed until the flight is over. For normal flying, however, most engine builders will advocate a change of oil after twenty hours of service.

Carbon formation and sludge are the essential reasons for such change, although metallic particles and perhaps dust or dirt may also be involved. These latter, however, will depend upon the degree to which the oil protects the engine and the extent to which the plane may operate at lower altitudes where the dust content of the air may be comparatively high.



Courtesy of Brownback Motor Laboratories, Inc.

Fig. 2—Sectional view of the Anzani radial type engine. Arrows and heavy black lines show path of oil through the lubricating system. Pressure lubrication prevails to all parts except piston pin bearings which are lubricated along with the cylinders by oil thrown from the connecting rod elements.

In general, dilution (during operation) will not be as extensively developed as in the average automotive engine, due in part to the fact that engine temperatures will be higher on account of more continuous service. On starting, however, priming with gasoline which will be frequently necessary may increase the initial rate of dilution of the oil in the lubricating system.

On the other hand, the considerably higher volatility of gasolines adaptable to aircraft engines will in itself be a deterrent to dilution. High volatility is indicative of absence of heavy ends or hydrocarbon fractions which will have a tendency to resist vaporization and remain in liquid form. Where these latter occur to any extent the ultimate result will be dilution or thinning down of the oil film on the cylinder walls. Where high volatility is an assured factor, however, as indicated by a correspondingly low end point, dilution will be markedly reduced.

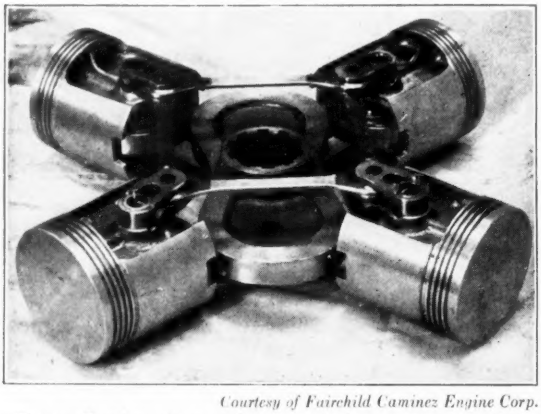
It is the opinion of certain authorities that but two or three per cent of diluent will develop from volatile aviation gasoline.

TYPES OF ENGINES

Aircraft engines can today be grouped into three broad classifications, according to the design and arrangement of their cylinders with respect to the crankshaft. These will include:

1. *The Fixed Radial Type*, wherein the cylinders are located at equal angular distances through a complete circle around the crankshaft. In such engines the cylinders are stationary, the crankshaft being the revolving element.
2. *The Rotary Type*, where, in contrast, the cylinders revolve around a fixed crankshaft. In the rotary engine cylinder spacing is equiangular just as in a radial engine.
3. *The In-Line or Linear Type*, where cylinders are located in line as in an automotive engine. Where but one row of cylinders are involved the engine is termed Vertical. Where there are two linear rows, it is known as a Vee type. Where three rows of cylinders are involved to form an inverted arrowhead it is termed a W type;

and where cylinders are opposed, that is, where two Vee type engines are set with one inverted, the arrangement is called an X type. The Vee type engine may also



Courtesy of Fairchild Caminez Engine Corp.

Fig. 3—Showing piston and cam operating arrangement of the Fairchild Caminez engine. This is a four-cylinder engine with the cylinders arranged radially about the central cam. Rotation of this latter is brought about by contact with a suitable roller mounted on each piston pin.

be built inverted, to enable greater pilot visibility.

The Radial, the Vertical and the Vee type engines are the three outstanding designs in military and commercial service in the United States today.

Radial and Rotary Engine Details

The essential features of such engines are their low weight per horse power, their adaptability to air cooling, their relatively short length, the accessibility of valves and cylinder heads, and the ease with which they can be mounted or detached. They offer fairly high wind resistance, however, by reason of their frontal area. This will be especially true of engines of higher horsepower.

Three to eleven cylinders will normally be employed in such engines, according to their intended horse power. Where cylinders are arranged equiangularly, in a single bank and served by the one crank connection, the number must be odd. This is the most usual construction in the modern radial engine. The four-cycle principle is used entirely. Such engines are of the valve-in-head type.

Radial Engine Lubrication

Full pressure lubrication is employed in the modern radial engine. In contrast with automotive practice such engines usually operate with a dry sump. In other words, oil, while maintained in constant circulation through the engine wearing elements, is not accumulated in a crankcase or sump as part thereof. Instead, it is removed by suitable scavenger pumps and led to an outside tank, where it is cooled and recirculated by the oil pressure pump. Such pumps may be of the plunger or gear type; the latter predominate.

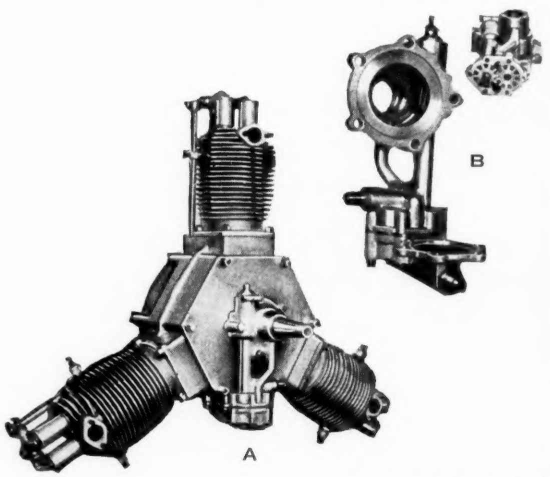
Oil, as it passes from the pressure pump, is discharged via a main distributing line to the main bearings, crankpin and connecting rod elements; from there it is carried to the piston pins and cylinder walls by centrifugal force.

Rotary Engine Lubrication

In engines of this type lubrication may be said to generally function according to the principles of the all-loss system. In other words, there is no re-circulation involved, oil being completely used up in its course through the engine. As a result such engines will show a comparatively high oil consumption.

One pump will therefore only be necessary in such engines, *i.e.*, for initial delivery of the oil to the main bearings, crank connections and cam gear. From this point lubrication of piston pins and cylinder walls is brought about by the action of centrifugal force on such excess oil as passes through the pressure lubricated bearings.

Where gasoline is passed through the crankcase prior to delivery to the combustion chambers, there will of course be contact between fuel and lubricating oil. This latter must, therefore, be a non-miscible product; that is, it must not tend to become cut back or reduced in viscosity by gasoline. For this reason castor



Courtesy of O. E. Szekely Corp.

Fig. 4—The Szekely three-cylinder radial type engine (A), with its oil pump shown at (B). The oil pump and lines are located within the engine. This pump is of the geared type, with pressure and scavenging elements combined as two sections.

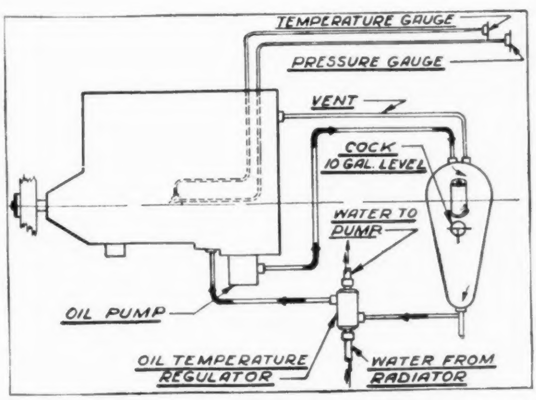
oil is used in such types of rotary engines. Petroleum lubricants cannot serve the purpose, as has been already mentioned in an earlier part of this article.

Linear (In-Line) Engine Details

Cylinder arrangement where linear or in-line type engines are involved will depend upon power requirements, frontal area limitations and fuselage design. Where six cylinders or less are desirable vertical arrangement is preferred, due to low frontal area and the practicability with which installation can be effected. When power requirements call for eight or more cylinders, however, the Vee type is most commonly adopted.

In such engines a 45, 60 or 90 degree angle will usually prevail, one crank being provided for each pair of cylinders in the same cross plane. The angle of the Vee will, of course, control the ultimate frontal area. As a result it will frequently be advantageous to reduce the Vee as much as possible. The 12 cylinder Liberty engine, for example, is built with a 45 degree Vee. There are other twelves, however, which have a 60 degree Vee, just as there are eights with a 90 degree Vee. Present day practice indicates preference of the two former angles due to the more even firing obtainable.

Engines of the W and X type are less commonly used in modern practice today, although extensive research in regard to the latter for high speed purposes is being carried on. In the W type engine there are three rows of cylinders, the center one being vertical, the side rows forming equal angles therewith. A typical W type engine will involve twelve cylinders and four cranks—one for each set of three cylinders. Overall length is, of course, reduced by a W type engine, but frontal area is markedly increased.



Courtesy of Curtis Aeroplane & Motor Co., Inc.

Fig. 5—Oiling system of the Curtis D-12 engine. Note in particular the oil temperature regulator and the provisions for using radiator water for maintenance of proper oil temperatures.

This will hold true likewise for the X type engine. In addition such engines will be considerably higher, requiring perhaps special fuselage design and construction. From a front view an X type engine may appear to be akin to a radial engine except that all four cylinders will not be spaced equiangularly. The same angle, however, must prevail between each upper and lower pair.

Courtesy of S. K. F. Industries, Inc.

Fig. 6—The main shaft of the Fairchild Caminez engine. At the rear it is supported by an S. K. F. roller bearing, at the front by a Hess-Bright deep-groove ball bearing. This latter also serves as the propeller thrust bearing. Study of this illustration along with Fig. 3, will show relation of pistons to cam and main shaft.

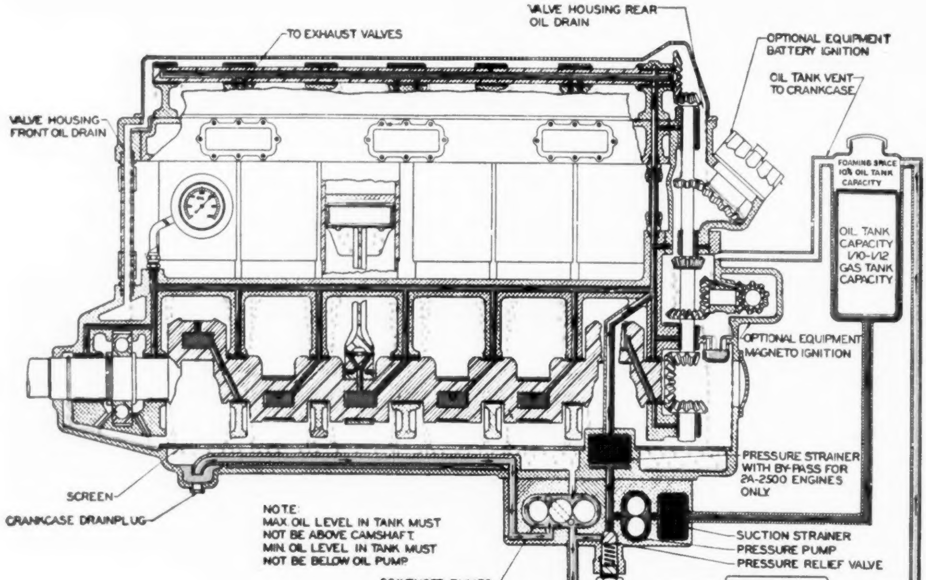
Up to the present time water cooling of linear type engines has been the most used, although air cooling of the Liberty engine, for example, has been found to be entirely practicable.

Principles of Lubrication

Pressure lubrication with a dry sump is almost universally preferred in engines of the linear type, just as holds true for the radial engine. The value of the dry sump is that it eliminates the possibility of uncovering of the oil inlet or flooding of cylinders with oil when a plane must dive, climb, bank or loop.

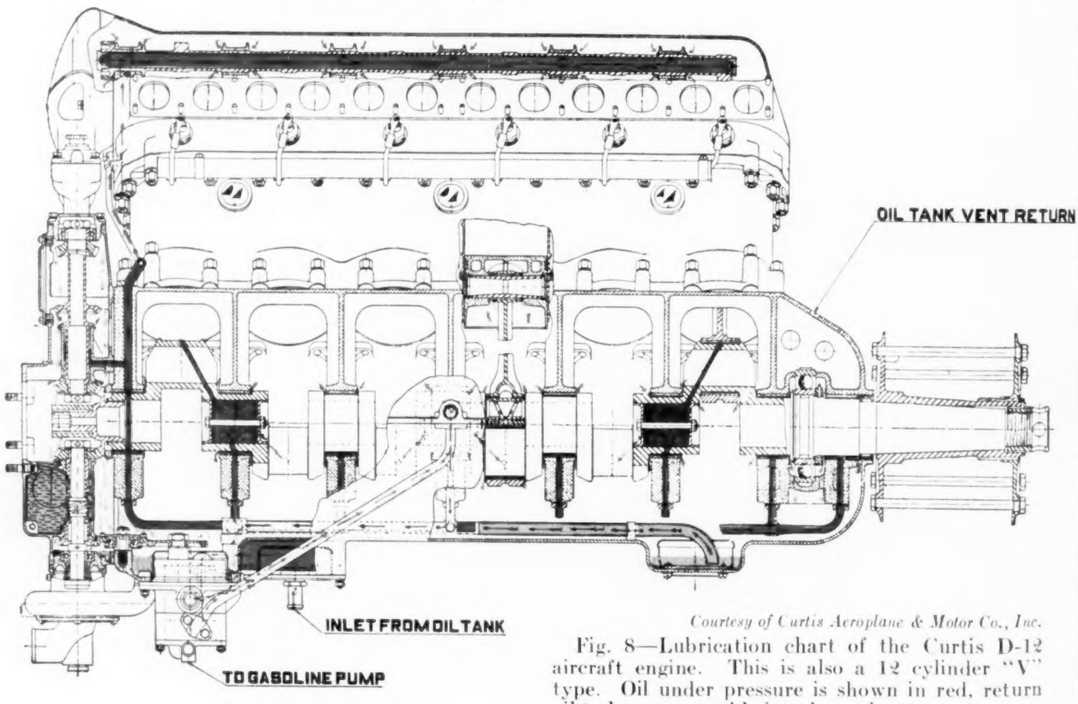
The modern linear type engine is therefore equipped with a pressure pump for delivery of oil and scavenger pumps for return of used oil to an oil cooler and storage tank located outside of the engine. The practicability of installing an oil cooler for warm weather flying or a heater for low temperature service is a feature of the dry sump system. The outstanding advantage however, is the assurance of positive lubrication, regardless of the position of the engine during flight.

As in the radial engine, the gear type oil pump is preferred for handling of lubricant to and from the working elements of the linear engine. The general course followed by the oil is from the storage tank to the pressure pump



Courtesy of Packard Motor Car Co.

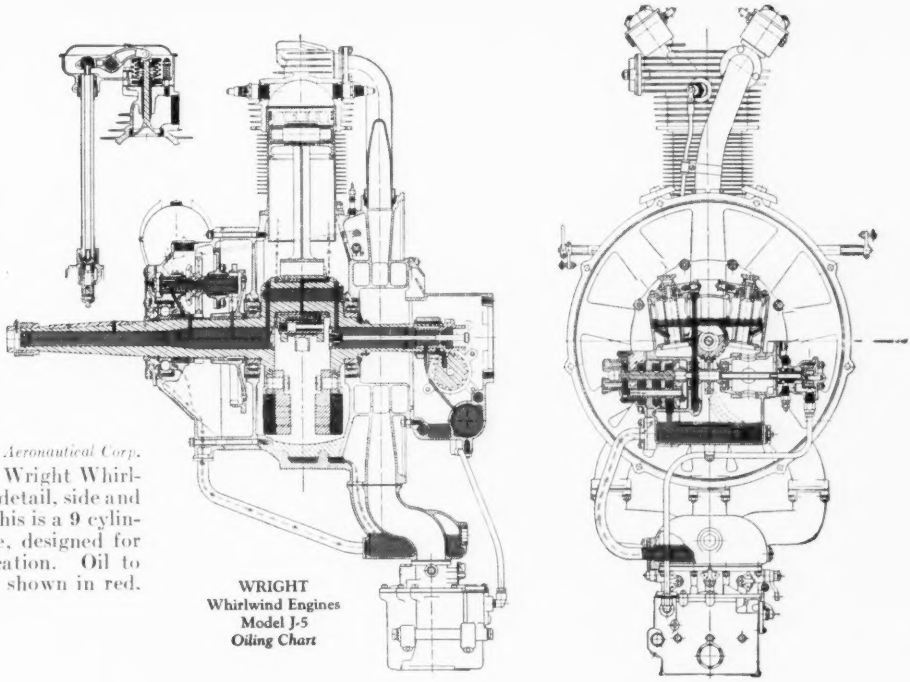
Fig. 7—Sectional side view and oiling diagram of the Packard 12 cylinder, "V" type aircraft engine, (models 2 A-1500 and 2 A-2500). Red shows oil supply under pressure to engine, green shows return oil and system of scavenging.



Courtesy of Curtis Aeroplane & Motor Co., Inc.

Fig. 8—Lubrication chart of the Curtis D-12 aircraft engine. This is also a 12 cylinder "V" type. Oil under pressure is shown in red, return oil to be scavenged being shown in green.

Lubrication Charts fo

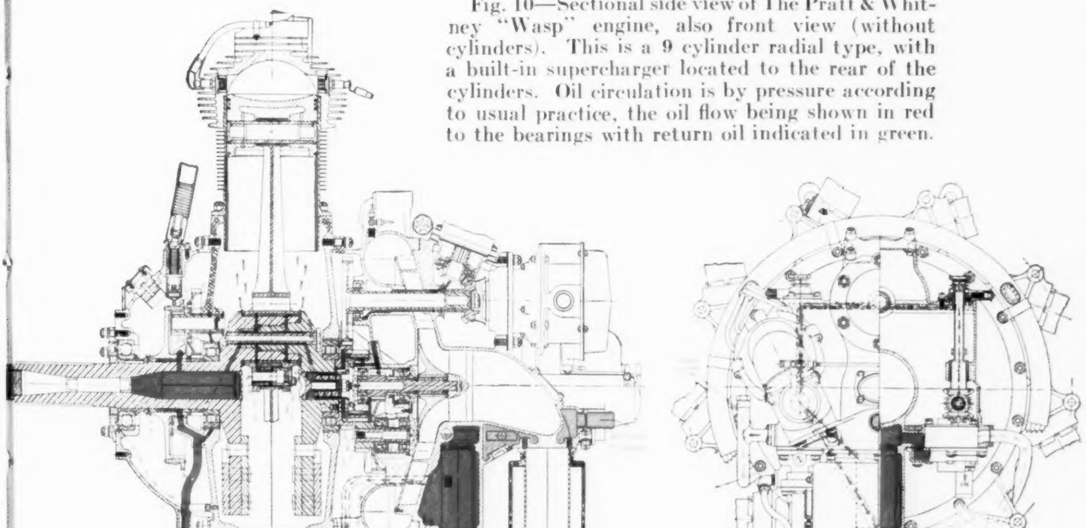


Courtesy of Wright Aeronautical Corp.

Fig. 9—The Wright Whirlwind engine in detail, side and front views. This is a 9 cylinder radial type, designed for pressure lubrication. Oil to bearings being shown in red.

Courtesy of The Pratt & Whitney Aircraft Co.

Fig. 10—Sectional side view of The Pratt & Whitney "Wasp" engine, also front view (without cylinders). This is a 9 cylinder radial type, with a built-in supercharger located to the rear of the cylinders. Oil circulation is by pressure according to usual practice, the oil flow being shown in red to the bearings with return oil indicated in green.



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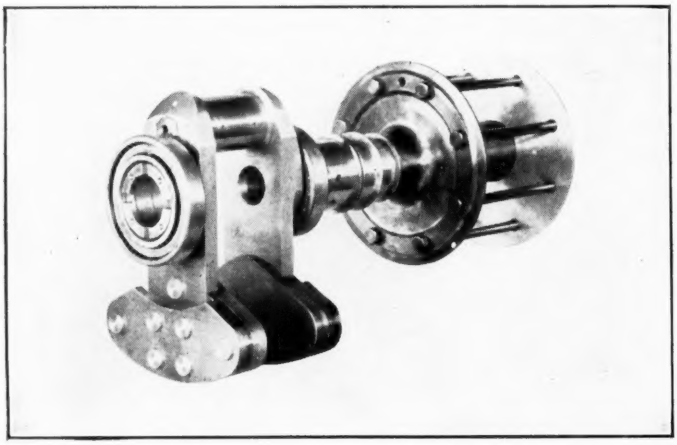
in the crankcase, thence via a main distributing line to serve the main bearings. Through suitable holes drilled in the crank, oil is then delivered under virtually the same pressure to the crank pin bearings through the drilled or hollow part of the crank pins.



Courtesy of S. K. F. Industries, Inc.
Fig. 11—Crankshaft of the Pratt & Whitney engine equipped with S. K. F. anti-friction bearings.

Where full pressure is desired the connecting rods may be drilled for subsequent delivery of oil up to the piston pin bearings, or else oil may be carried up via a separate oil tube attached to each rod. Otherwise, the piston pins are lubricated simultaneously with the cylinder walls, by oil thrown from the connecting rod bearings and also from the main bearings.

Camshaft bearings and timing gear are usually served by a direct oil line from the main bearing distributing system. Where the camshaft is hollow it serves as a transmission main to carry oil to each respective bearing via suitable discharge holes.

Return oil as it passes through the wearing elements of the engine finds its way to the base of the crankcase and thence to the scavenging pumps for delivery to the oil cooler or heater, and finally to the storage tank when it is ready for re-delivery.

A considerable volume of lubricating oil must be available to serve such a system effectively and permit of an adequate period of rest. In the average engine, the rate of circulation will range from 2 to 6 gallons per minute. The volume to be carried will to an extent depend upon the size of the engine and its intended flying period. Packard provides a storage tank having an oil capacity of from 1/10 to 1/12 the gasoline tank capacity.

ENGINE COOLING

In the operation of an aircraft engine it is important to remember that it is virtually impossible to shut down for the purpose of cooling, for any length of time. Landing must be made if this is necessary. If forced down serious consequences may result.

It is therefore most essential to provide for adequate means of cooling and protection of lubrication while in the air, by either suitable water jacketing where a water-cooled vertical or Vee type engine is involved, or by an arrangement of fins on each cylinder in the air-cooled radial or rotary engine.

Effective lubrication of cylinder walls especially is directly contingent upon the extent to which they are cooled. Combustion temperatures are comparatively high and it is virtually impossible to prevent transfer of more or less heat to the lubricating film. It is practicable, however, to control the rate of heat transfer and the temperature of the cylinder walls, to thereby prevent dangerous reduction in the viscosity of the oil. In the beginning only cylinder walls and piston rings would be affected by the oil being too thin, but due to the fact that heat transfer occurs within the main body of the oil in the system, the bearings would very soon suffer likewise, even to the point of seizure.

As stated, control of engine temperatures is maintained by air or water cooling. Where direct air cooling is provided for, as in the radial engine, weight per horse power is reduced and no intricate mechanisms are involved other than suitable fin construction on the cylinders. In the water cooled engines, however, the circulating system, pump and radiator must be considered. All involve additional weight. In addition there is the weight of the water which must be carried. Water cooling is, of course, but an indirect form of air cooling, for the water after taking up heat from the engine is reduced in temperature by radiation prior to re-circulation.

Water cooling, while involving more accessory engine equipment, may enable operation at somewhat higher engine speeds, although this advantage is claimed to be reduced by the most modern radials. Higher speeds would be advantageous in war time, or where racing planes are involved.

Water cooling also permits of more ready control of engine temperatures and affords more reserve cooling. This is a distinct factor

just as in the automotive engine, where complete combustion, fuel economy and maximum engine efficiency are under consideration.

PRINCIPLES OF ENGINE BEARING CONSTRUCTION

The aircraft engine will in general be found to employ bearings of the sleeve or anti-friction type. In the vertical or Vee engine the plain or sleeve type bearing is extensively used. The principles of lubrication of such engines, with design of the lubricating system, are very similar to those involved in the average automotive engine. The most outstanding difference is the exclusion of oil supply from the crankcase by use of the dry sump system, of which the basic details of operation have already been discussed.

There is marked tendency, however, towards adoption of the anti-friction (ball or roller) bearing, especially in the radial type of engine, although such elements have also been found adaptable to connecting rod bearings, for example, in certain Vee type engines.

Sleeve Type Bearings

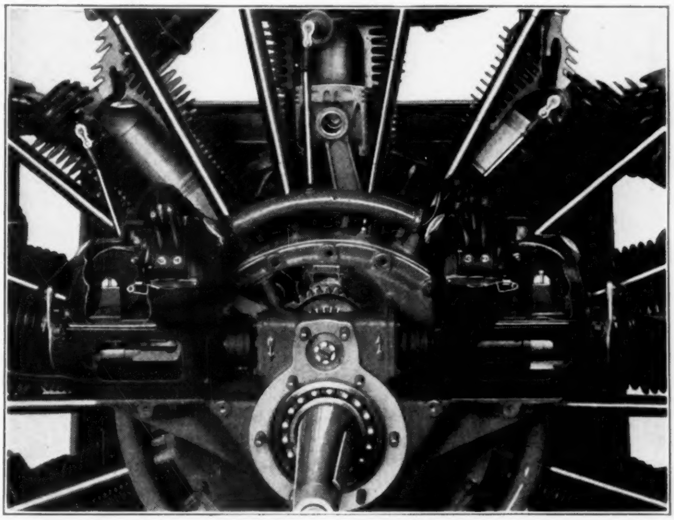
Where bearings of this type are involved the essential problem which must be solved in lubricating will be to maintain a continuous oil film within the extremely small clearance spaces, regardless of operating temperature fluctuations.

Bearing Clearance

As a general rule the amount of clearance which will be found in the plain bearings of an aircraft engine will frequently be greater than in an automotive engine, although clearances will, of course, vary according to the size of the shaft or pin.

Experience indicates that an allowed clearance of 0.001 inch for each inch of shaft or pin diameter will result in the maintenance of effective lubrication and the development of the least amount of wear, provided, of course, that the lubricating oil is suited to the operating conditions involved.

It is important to remember that such bearings must be as light as possible within the limits of strength required, in order to reduce weight. This is partly the reason why pins and shafts in most cases are of hollow construction. As a result, lubrication must be absolutely positive at all times to insure complete filling of the clearance space, and removal of heat. In fact, oil flow, while it serves to lubricate, also affords a most effective means of bearing temperature control. Under the intensive duty involved it is logical to presume that without such a means of removal of heat by oil circulation, bearing temperatures would quickly rise to such a degree as to preclude safe engine



Courtesy of Standard Steel and Bearings, Inc.

Fig. 12—The Wright Whirlwind engine in section showing in particular the cylinder construction with provisions for air cooling and the S. R. B. ball bearing installation for carrying the main shaft, and the thrust of the propeller.

operation. Such heat as is taken up by the engine oil in circulation is subsequently removed in turn by the oil cooler or tank through which return oil is passed prior to re-circulation.

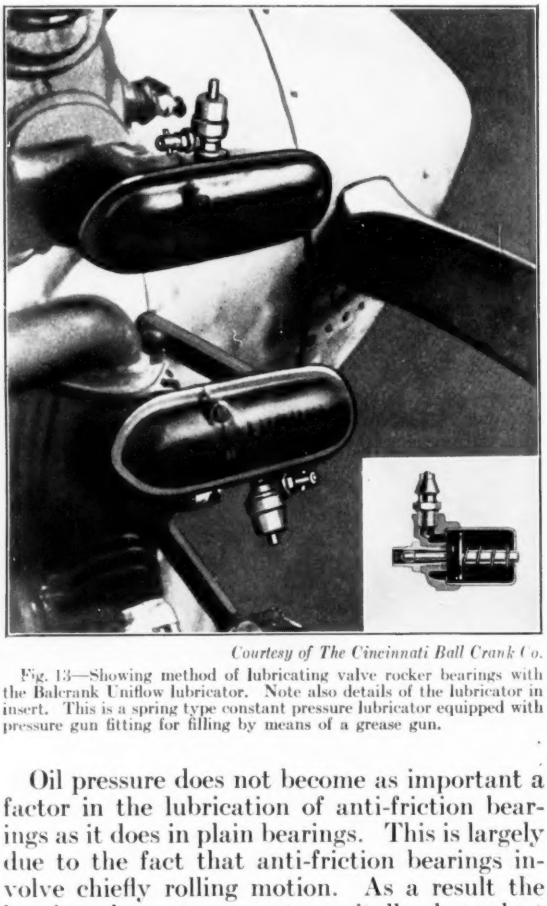
Plain bearings as found in aircraft engine service today will differ from those in certain other types of machinery in regard to their manner of oil grooving. As a rule there will be fewer grooves cut, or frequently none at all. Perhaps the reason for this is to avoid decreasing bearing area to any marked degree, inasmuch as removal of bearing metal to form a path for oil to follow interferes with wedge action in the formation of the lubricating film, and also reduces the effective bearing area.

It must also be understood, however, that where bearings are pressure lubricated, as in the aircraft engine, there will not be the same need for oil grooves, for distribution will be maintained by the pressure on the oil at the points of delivery. This pressure can, of course, be varied according to the probable working pressures to be encountered. Automatically it will vary with bearing temperatures. For example, it will be comparatively high when cold starting. As the engine bearings warm up, however, the viscosity or body of the oil will be reduced, facilitating more ready flow through the clearance spaces, with less pressure to bring this about.

Anti-Friction Bearings

The essential advantages pertaining to the ball or roller bearing in aircraft engine service will involve:

1. Less lubrication, and
2. Reduction in overall length of the engine.



Courtesy of The Cincinnati Ball Crank Co.

Fig. 13—Showing method of lubricating valve rocker bearings with the Balcrank Uniflow lubricator. Note also details of the lubricator in insert. This is a spring type constant pressure lubricator equipped with pressure gun fitting for filling by means of a grease gun.

Oil pressure does not become as important a factor in the lubrication of anti-friction bearings as it does in plain bearings. This is largely due to the fact that anti-friction bearings involve chiefly rolling motion. As a result the bearing elements are not so vitally dependent upon the lubricating film as in a plain bearing where sliding motion is involved. Furthermore, there will normally not be the same tendency towards heat development. In fact, the higher the load or speed the more advantageous will an anti-friction be, due in part to the lower amount of heat developed and therefore the greater ease with which engine bearing temperatures can be maintained as desired.

Propeller Thrust Bearings

A most interesting instance of application of the ball bearing is the propeller thrust bearing on certain types of engines. The purpose of such a bearing is to take up end thrust along the shaft as it is developed by the propeller.

Such bearings, where advantageously located, will usually be lubricated via the main oiling system by a spray of oil from the overflow from some adjacent main bearing.

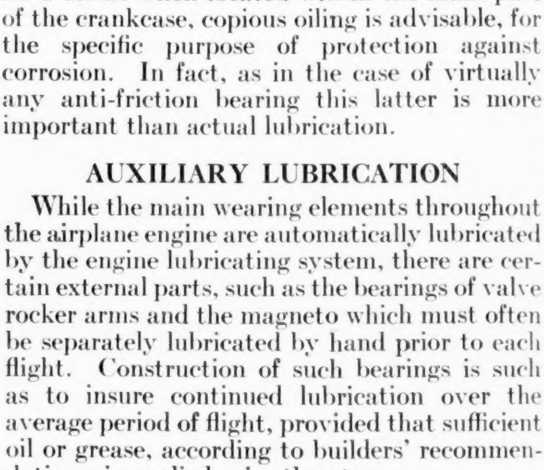
All such thrust bearings, however, cannot always be so served. Sometimes they will be so located as to require individual lubrication via an oil lead installed for this particular purpose. Especially will this be true where such bearings are located so as to be free from exposure to crankcase vapors. These latter may often be corrosive, tending thereby to have a deleterious effect upon the highly polished rolling elements which constitute the bearing. As a result when located within the main part of the crankcase, copious oiling is advisable, for the specific purpose of protection against corrosion. In fact, as in the case of virtually any anti-friction bearing this latter is more important than actual lubrication.

AUXILIARY LUBRICATION

While the main wearing elements throughout the airplane engine are automatically lubricated by the engine lubricating system, there are certain external parts, such as the bearings of valve rocker arms and the magneto which must often be separately lubricated by hand prior to each flight. Construction of such bearings is such as to insure continued lubrication over the average period of flight, provided that sufficient oil or grease, according to builders' recommendations, is applied prior thereto.

Valve Rocker Arm Bearings and Rollers

Rocker arm bearings are usually designed today for grease gun lubrication, being equipped



Courtesy of Scintilla Magneto Co., Inc.

Fig. 14—Sectional side view of an aircraft engine magneto. At 4 and 11 are shown the front and rear oil holes. Note the ball bearing mountings which carry the rotating magnet 9. The distributor gear, 5, however, is carried by a plain bearing. This latter is wick oiled.

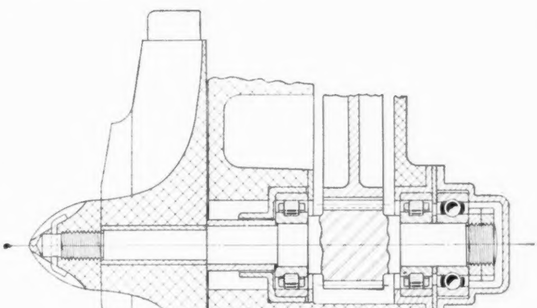
with a suitable pressure gun fitting at each bearing. Common practice is to use a plain or sleeve type bearing to carry the rocker arm, or else a ball or roller bearing, according to the design of the engine. Either type will prove satisfactory and efficient, provided that lubri-

cation is properly and regularly carried out in order to assure of continued operation, with a minimum of wear and possibility of valves sticking.

The proper lubricant to use for such bearings will depend upon the extent to which their housings will retain oil. In many cases a heavy oil of about the viscosity of an extra heavy airplane engine lubricant will be satisfactory. Such a viscosity would be in the neighborhood of 115 seconds Saybolt at 210 degrees F.

On the other hand, where high altitude flying is involved, or in cold weather, it may be advantageous to resort to a semi-fluid grease which has a low pour test oil content. Gumming, of course, must be guarded against, otherwise faulty lubrication may occur. This might be very apt to develop in low temperature operation, were a heavy oil of comparatively high pour test used, for the amount of heat transmitted to such bearings will be slight. Properly compounded grease, however, will have adequate body to remain within the bearing at normal temperatures, and also adequate fluidity by virtue of its low pour test oil content to maintain lubrication at low temperatures.

Such lubricants can also be used to wipe the rocker rollers or ball contacts at the same time that rocker arm bearings are lubricated. A light film on these will suffice to effectively prevent abnormal wear.



Courtesy of Norma-Hoffmann Bearings Corp.

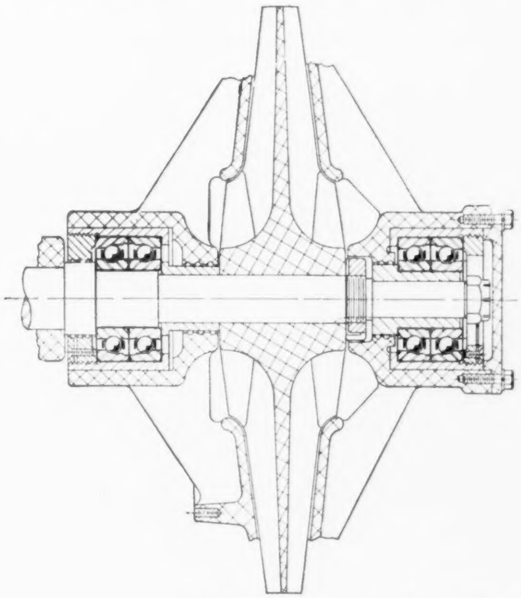
Fig. 15—A high speed supercharger equipped with Hoffmann roller bearings to carry the radial load, and a deep groove ball bearing which carries end thrust.

Magneto Bearings

Lubrication of magneto bearings is of vital importance in connection with operation of the aircraft engine. Ignition must be positive and assured, otherwise serious difficulty may result.

The ball bearing distributor has, therefore, been extensively adopted by aircraft magneto manufacturers, by reason of its elimination of lubrication troubles and the possibility of burning out or seizure of distributor wearing elements.

Adequate housing of ball bearings will assure positive retention of oil, and re-lubrication is



Courtesy of Norma-Hoffmann Bearings Corp.

Fig. 16—It is also practicable to equip the supercharger with open-type ball bearings throughout, as shown above.

only essential at infrequent intervals. Every ten flying hours has been developed as being the proper period for oiling during operation, using a highly refined straight mineral lubricant of approximately 200 to 300 seconds Saybolt at 100 degrees F. Zero pour test or better is extremely necessary in such an oil to insure adequate fluidity at low temperature operation.

The amount of oil to use should be determined from the magneto manufacturer. In the Scintilla, for example, 30 to 40 drops of oil should be applied to the front bearing oil holes, with from 3 to 5 drops in the rear bearing oil hole.

Grease lubrication is also necessary on some magneto bearings, provision being made for packing. By virtue of the design and location of such bearings, re-lubrication is only necessary at the time of engine overhaul, when it is reasonable to presume that magnetos should be similarly overhauled. For such bearings, a fibrous grease of medium consistency, capable of standing from 180 to 200 degrees F. should be used.

THE SUPERCHARGER

The purpose of the supercharger on an airplane engine is to enable high altitude flying

under as nearly as possible sea level atmospheric conditions within the engine. In other words, rarified air as encountered above the earth must be concentrated prior to delivery to the carburetor. Otherwise it will be impossible to maintain the intended gaseous mixture. This would amount to delivery of too rich a mixture, to result in faulty engine operation, dilution and abnormal carbon formation.

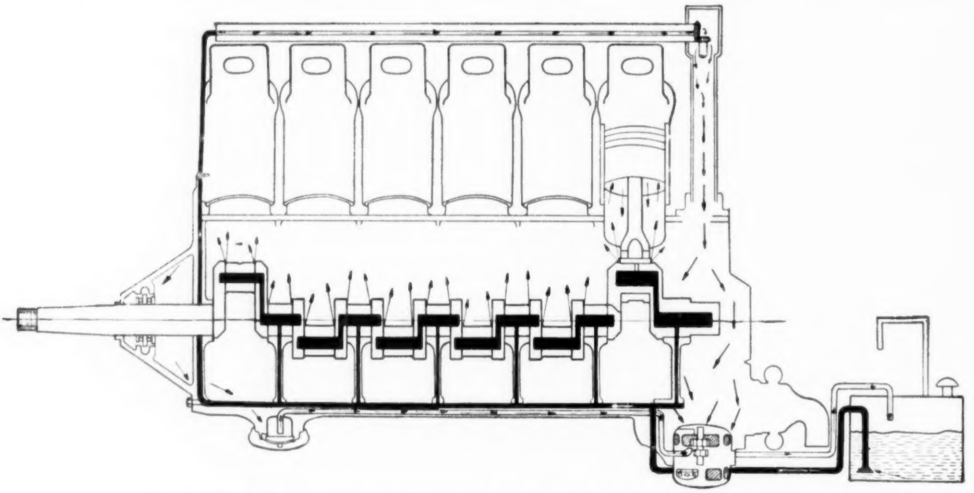


Fig. 17—Lubricating system for the Liberty "12-A" engine. Path of oil is shown in heavy black outline with arrows to indicate direction.

Engine power will depend upon altitude, varying directly as the density of the air involved. At an altitude of 20,000 feet, for example, the brake horse power will be only about half that developed at sea level.

Suitable compression of air, however, by means of some form of compressor or blower and delivery to the carburetor at a pressure approximating sea level conditions as mentioned above, will result in effective maintenance of engine speed and power.

Supercharging can be accomplished by using either a centrifugal, rotary or reciprocating device. The latter, although adaptable where intermittent delivery of air may be practicable, is virtually obsolete today. The centrifugal and rotary compressor are, however, both highly favored, even though they may sometimes involve greater carburetor strength due to the higher pressures involved. With such compressors continuous pressure is involved, being exerted upon the entire volume of air used in combustion.

The operating speed of such a device will depend upon its manner of drive. This, of course, is derived from the engine. It can be brought about by gear drive or by employing the principle of the turbine using exhaust gas as the impelling medium. The latter is capable of developing perhaps the highest speed, although the modern gear drive has been run up to 30,000 r.p.m. where necessary.

Installation of a supercharger may be external or internal according to the type of engine. In a Vee engine the usual practice is to locate this device to the rear of the engine. In the radial engine, however, the supercharger is almost always built into the engine where it acts as a rotary distribution system at part throttle and as a supercharger at full throttle.

Where such construction prevails lubrication of bearings and driving gears is brought about through suitable leads from the main oiling system, under the same pressure as is directed to the engine bearings. Not only is lubrication thereby positively attained, but also cooling of gears especially is brought about by the flood of oil which is directed to them.

CONCLUSION

To discuss this most important matter of aircraft engine lubrication with fitting completeness would require far more space than afforded by a single issue of LUBRICATION. Our text has, therefore, touched only upon the high spots, with just enough descriptive data to arouse the interest of the layman. The utmost care has, however, been observed in the selection of our illustrations for it is felt that these will round out our article and amplify our information on engine construction, lubrication system design and oil requirements. The aircraft engine and its accessory equipment must be most accurately designed, most carefully constructed and most positively lubricated. If our data serves but to stress the importance of the above it will have served its purpose in the interests of dependable aerial transportation.

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